Increasing Postoperative Ventilation:
A Comparison of Five Methods

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Various programs for prevention of pulmonary difficulties in the immediate postoperative period have been introduced. Basic to all such regimens are measures for periodically increasing tidal volume, thereby permitting lung expansion, effective coughing and mobilization of secretions. In this study of 15 individuals who had recently undergone thoracotomy or laparotomy, five commonly employed methods of enhancing ventilation used sequentially in each patient were compared in regard to their effectiveness in increasing tidal volumes.

METHODS

Fifteen patients, 12 men and three women, formed the study group. Their ages ranged from 23 to 78 years, and seven were more than 60 years old. Nine patients had undergone thoracotomy; five, upper abdominal surgery; one, combined thoracotomy and laparotomy.

All patients were studied in the Pulmonary Laboratory two to five days postoperatively, after nasogastric and chest tubes had been removed. The majority were evaluated on the second or third day following surgery. All had some discomfort arising from their incisions, but none had received narcotics within four hours of the study. Measurements of minute volume, respiratory frequency, and mean tidal volume were made for each patient in the sitting position in the following sequence: at rest; during voluntary deep-breathing for two minutes; during use of the Adler Rebreather (a disposable unit of 1,000-cc volume) for five minutes; during IPPB using a Bennett PR-2 respirator set for low flow rates at 15 cm water end-inspiratory pressure for two minutes (IPPB-15) and then at 25 cm water end-inspiratory pressure for two minutes (IPPB-25); during inhalation of 5 per cent carbon dioxide in oxygen for five minutes. Measurements were made continuously, but only the final minute of each period was used for calculations. The subjects rested for ten minutes between parts of the study.

Six patients had identical studies preoperatively.

RESULTS

In the six patients studied both before and after surgery, tidal volumes achieved postoperatively by voluntary deep-breathing decreased in all instances, averaging 68 per cent of the preoperative values. Hence, it is apparent—as is obvious clinically—that there is indeed diminished ventilatory ability following abdominal or thoracic surgery.

Results of the postoperative studies are presented in figure 1 wherein the five methods are arranged along the horizontal axis and the per cent changes in tidal volumes relative to resting levels along the vertical axis. The shaded bars indicate mean increases in tidal volume achieved by each method. An increase in tidal volume of 100 per cent or more was regarded as satisfactory.

With the Adler Rebreather, tidal volumes in 9 patients failed to increase by as much as 50 per cent, and only two patients (13 per cent) had increments of 100 per cent or more. This was clearly the poorest method.

When 5 per cent carbon dioxide was inhaled for five minutes, overall results were somewhat better. A third of the subjects had only minimal (less than 50 per cent) increments in tidal volumes above resting levels, while another third had moderate (50 to 100 per cent) increments. Tidal volumes of the remaining five patients (33 per cent) increased by 100 per cent or more.

When the results with IPPB-15 were considered, it was evident that the group was almost equally divided between those with mini-
nal and those with satisfactory changes in tidal volumes. In seven patients ventilation was not augmented by more than 50 per cent, and two of these who could not coordinate their breathing well with the apparatus actually showed decreased tidal volumes. In seven other individuals (46 per cent), however, tidal volumes increased satisfactorily by 100 per cent or more.

Voluntary deep-breathing was minimally effective in five patients. In the remaining ten patients tidal volumes increased by 80 per cent or more. Eight individuals (53 per cent) were able to more than double ventilation.

IPPB-25 was detrimental in one patient and produced only minimal improvement in another; neither could coordinate breathing well with the apparatus. In the remaining 13 patients, however, tidal volumes increased by at least 75 per cent; in nine of them (60 per cent) by 100 per cent or more.

Mean percentage increases in tidal volume above resting levels are also presented in figure 1. These figures were 50 per cent for the Adler Rebreather; 80 per cent for inhalation of carbon dioxide; 90 per cent for IPPB-15; 105 per cent for voluntary deep-breathing; 175 per cent for IPPB-25.

The method yielding the highest tidal volume for each of the 15 patients was determined. The inhalation of 5 per cent carbon dioxide produced superior results in one, voluntary deep-breathing in two, and IPPB-25 in 12 patients. Tidal volumes at least 200 cc greater than those observed with any other method were achieved by one patient during carbon dioxide inhalation, by another during voluntary hyperventilation, and by five patients while using IPPB-25.

Since voluntary deep-breathing is the simplest of all these methods, a comparison of its effectiveness is presented in figure 2. Seven patients, approximately half the group, were able to increase their tidal volumes as effectively by deep-breathing as by any other method. In the remaining 8 patients, tidal volumes more than 200 cc greater than those obtained by deep-breathing alone were attributed to IPPB-15 in two patients, to CO₂ inhalation in three patients, and to IPPB-25 in seven patients.

**FIG. 1.** Results of postoperative ventilatory studies grouped according to the methods employed for increasing tidal volumes. Shaded bars indicate mean increases in tidal volumes with each method.

**DISCUSSION**

Pulmonary problems are the most common complications of upper abdominal surgery, occurring postoperatively in 20 to 50 per cent of patients.¹-⁴ The reported incidence of contralateral atelectasis after thoracotomy is 14 per cent.⁵ Without periodic pronounced increases in tidal volume, areas of lung are underventilated for long periods, ventilation-perfusion ratios are disturbed, air cannot penetrate beyond secretions in sufficient volume to permit their expulsion, and bacteria localize and multiply in poorly ventilated and obstructed segments.⁶ Hypoxemia, hypercarbia,
Fig. 2. Effectiveness of voluntary deep-breathing. Where this method alone did not produce the highest tidal volume, the effects of other techniques in increasing tidal volumes by at least 200 cc are shown.

atelectasis, pulmonary edema, pneumonitis and pulmonary abscess may occur singly or in combination as a result.

Various regimens for the prevention of these respiratory complications during the postoperative period have been introduced. Early mobilization of the patient and encouragement of deep-breathing are almost universally advocated. Stimulation of central respiratory receptors by carbon dioxide inhalation, first used for postoperative de-etherization in 1920, generally is accomplished by inhalation of a 5 per cent mixture of this gas with oxygen. A modification of this technique induces hypercapnia by increasing respiratory deadspace so that the patient rebreathes his expired carbon dioxide. The Dale-Schwart tube and the Adler Rebreather, both of which increase deadspace by 1,000 cc, have achieved popularity as simple, inexpensive bedside devices for increasing tidal volume. IPPB has been advocated enthusiastically for the prophylaxis of pulmonary complications by some (mainly on the basis of testimonial evidence); declared expensive, potentially harmful and, therefore, impractical by others; and found ineffective for this purpose in a single controlled study. Inspiratory pressures of 10 to 20 cm water were generally employed for postoperative patients in these reports.

The data from this study of five methods for enhancing postoperative ventilation permit the following conclusions: 1) Rebreathing was relatively ineffective in increasing depth of respiration. 2) IPPB, at the conventionally employed inspiratory pressure of 15 cm water, and the inhalation of 5 per cent carbon dioxide were methods of intermediate value. They were, however, only infrequently equal to or more effective than voluntary efforts in producing significant increases in tidal volumes. 3) Voluntary deep-breathing was frequently quite effective. Increases in tidal volumes of 80 per cent or more occurred in two-thirds of the subjects, while tidal volumes as large or larger than those produced by any other method were observed in approximately half the patients. 4) IPPB at the relatively high inspiratory pressure of 25 cm water was clearly the superior method. When tidal volumes greater than those due to voluntary deep-breathing were observed, these were almost always produced by IPPB-25.

The limitations of this study should be emphasized. Although ten-minute rest periods were interposed between ventilatory tests, it is possible that each patient did not always return to baseline resting levels of ventilation and $P_{aCO_2}$. Fatigue or facilitation of response by learning may have been sources of error, since a fixed sequence was followed in the administration of inflationary therapy. No attempts were made to assess the effectiveness of each method in the actual reduction of postoperative respiratory problems. Certainly the next logical step is a comparative evaluation of these methods in a larger series of patients wherein the method of augmenting tidal volume is the only variable in a comprehensive program for preventing pulmonary complications.

References


Rubber-Gas Partition Coefficients

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Current investigations aimed at developing closed-system quantitative anesthesia 1-3 require knowledge of the rate of anesthetic uptake by soda lime and rubber. Rubber-gas partition coefficients for halothane and methoxyflurane have been reported by Eger et al.4-5 to be 121 and 742, respectively. We have calculated partition coefficients of 11 volatile anesthetic agents from the anesthetic retention times on rubber chromatograph columns.

METHODS

Conductive rubber from a standard anesthesia breathing tube was pulverized with a motorized grindstone. Bureau of Standards sieves were employed to collect the fraction between 16 and 20 mesh. A weighed amount

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